TITLE OF THE INVENTION

OPTICAL PICKUP COMPATIBLE WITH A DIGITAL VERSATILE DISK AND A RECORDABLE COMPACT DISK USING A HOLOGRAPHIC RING LENS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001]   This application claims the benefit of Korean Application No. 97-11297, filed March 28, 1997, and U.S. Patent Application No. 09/419,792 filed in the U.S. Patent and Trademark Office on October 18, 1999, now pending, which is a continuation of U.S. Patent Application No. 09/049,988, which issued as U.S. Patent No. 6,043,912, the disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002]   The present invention relates to an optical pickup apparatus compatible with a digital video disk (DVD) and a recordable compact disk (CD-R), and more particularly, to an optical pickup apparatus which can compatibly record information on and read information from a digital video disk (DVD) and a recordable compact disk (CD-R), respectively, using a holographic lens.

Description of the Related Art

[0003]   An optical pickup apparatus records and reads the information such as video, audio or data at a high density, and various types of recording media are a disk, a card and a tape. Among them, the disk type is primarily used. Recently, in the field of the optical disk apparatus, a laser disk (LD), a compact disk (CD) and a digital video disk (DVD) have been developed. Such an optical disk includes a plastic or glass medium having a certain thickness along an axial direction to which light is incident, and a signal recording surface on which information is recorded and located on the plastic or glass medium.

[0004]   So far, a high-density optical disk system enlarges a numerical aperture of an objective lens to increase a recording density, and uses a short wavelength light source of 635 nm or 650 nm, Accordingly, the high-density optical disk system can record or read signals on or from a digital video disk, and can also read signals from a CD. However, to be compatible with a recent type of a CD, that is, a recordable CD (CD-R), light having a wavelength of 780 nm

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should be used, due to the recording characteristic of the CD-R recording medium. As a result, using the light beam wavelengths of 780 nm and 635 (or 650) nm in a single optical pickup becomes very important for compatibility of the DVD and the CD-R. A conventional optical pickup which is compatible with the DVD and the CD-R will be described below with reference to FIG. 1.

[0005]   FIG. 1 shows an optical pickup using two laser light diodes as light sources for a DVD and a CD-R and a single objective lens. The FIG. 1 optical pickup uses laser light having a wavelength of 635 nm when reproducing a DVD, and uses laser light having a wavelength of 780 nm when recording and reproducing a CD-R.

[0006]   Light having the 635 nm wavelength emitted from a first laser light source 11 is incident to a first collimating lens 12, in which the light is shown in a solid line. The first collimating lens 12 collimates the incident light beam to be in a parallel light beam. The light beam passing through the first collimating lens 12 is reflected by a beam splitter 13 and then goes to an interference filter prism 14.

[0007]   Light having the 780nm wavelength emitted from a second laser light source 21 passes through a second collimating lens 22, a beam splitter 23 and a converging lens 24, and then goes to the interference filter prism 14, in which the light is shown in a dotted line. Here, the light beam of the 780 nm wavelength is converged by the interference filter prism 14. An optical system having such a structure is called a "finite optical system." The interference filter prism 14 totally transmits the light beam of the 635 nm wavelength reflected from the beam splitter 13, and totally reflects the light beam of the 780 nm wavelength converged by the converging lens 24. As a result, the light beam outgoing from the first laser light source 11 is incident to a quarter-wave plate 15 in the form of a parallel beam by the collimating lens 12, while the light beam from the second laser light source 21 is incident to the quarter-wave plate 15 in the form of a divergent beam by the converging lens 24 and the interference filter prism 14. The light transmitted through the quarter-wave plate 15 passes through a variable aperture 16 having a thin film structure and then is incident to an objective lens 17.

[0008]   The light beam of the 635 nm wavelength emitted from the first laser light source 11 is focused by the objective lens 17 on an information recording surface in the DVD 18 having a thickness of 0.6 mm. Therefore, the light reflected from the information recording surface of the DVD 18 contains information recorded on the information recording surface. The reflected light

is transmitted by the beam splitter 13, and is then incident to a photodetector for detecting optical information.

[0009] If the finite optical system described above is not used, when the light beam of the 780nm wavelength emitted from the second laser light source 21 is focused on an information recording surface in the CD-R 25 having a thickness of 1.2mm using the above described objective lens 17, spherical aberration is generated due to a difference in thickness between the DVD 18 and the CD-R 25. The spherical aberration is due to the fact that the distance between the information recording surface of the CD-R 25 and the objective lens 17 is farther than that between the information recording surface of the DVD 18 and the objective lens 17, along an optical axis. To reduce such a spherical aberration, a construction of a finite optical system including the converging lens 24 is required. By using the variable aperture 16 to be described later with reference to FIG. 2, the light beam of the 780 nm wavelength forms an optimized beam spot on the information recording surface of the CD-R 25. The light beam of the 780 nm wavelength reflected from the CD-R 25 is reflected by the beam splitter 23, and then detected in a photodetector 26.

[0010] The thin-film type variable aperture 16 of FIG. 1, as shown in FIG. 2, has a structure which can selectively transmit the light beams incident to the regions whose numerical aperture (NA) is less than or equal to 0.6, which coincides with the diameter of the objective lens 17. That is, the variable aperture 16 is partitioned into two regions based on the numerical aperture (NA) of 0.45 with respect to an optical axis. Among the two regions, a first region 1 transmits both light beams of 635 nm wavelength and 780nm wavelength. A second region 2 totally transmits the light beam of the 635 nm wavelength and totally reflects the light beam of the 780 nm wavelength. The region 1 is a region having a numerical aperture less than or equal to 0.45, and the region 2 is an outer region relative to the region 1 in which a dielectric thin film is coated. The region 1 is comprised of a quartz (5102) thin film to remove any optical aberration generated by the dielectric thin film coated region 2.

[0011] By using the variable aperture 16, the 780 nm wavelength light transmitted through the region 1 having the 0.45 NA or below forms a beam spot appropriate to the CD-R 25 on the information recording surface thereof. Thus, the FIG. 1 optical pickup uses an optimum beam spot when a disk mode is changed from the DVD 18 to the CD-R 25. Accordingly, the FIG. 1 optical pickup is compatible for use with the CD-R.

[0012]   However, the optical pickup shown in FIG. 1 and as described above should form a "finite optical system" with respect to the 780 nm wavelength light in order to remove any spherical aberration generated when changing a DVD compatibly with a CD-R. Also, due to the optical thin film, that is, the dielectric thin film, which is formed in the region 2 of the variable aperture 16 having the NA of 0.45 or above, an optical path difference between the light transmitted through the region 1 having the NA of 0.45 or below and that transmitted through the region 2 having the NA of 0.45 or above, is generated. To eradicate this difference, it is necessary to form an optical thin film in the region 1. Due to this reason, a quartz coating (SiO$_2$) is formed in the region 1 and a multi-layer thin film is formed in the region 2. However, such a fabricating process does not only become complicated but also adjustment of the thickness of the thin film should be performed precisely in units of "μm". Thus, it has been difficult to mass-produce the optical pickup.

SUMMARY OF THE INVENTION

[0013]   An object of the present invention is to provide an optical pickup apparatus which is compatible with a digital video disk (DVD) and a recordable compact disk (CD-R), by adopting an infinite optical system and using a holographic lens to remove a spherical aberration generated due to a difference in thickness between optical disks.

[0014]   Additional objects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0015]   To accomplish the above and other objects of the present invention, there is provided an optical pickup apparatus compatible with at least two types of optical recording media, using light beams having respective different wavelengths for recording and reading information, the optical pickup apparatus including two laser light sources to emit light beams having different wavelengths, respectively, a holographic lens, including a holographic ring, for transmitting both of the light beams emitted from the two laser light sources in an inner region of the holographic ring, and diffracting a specific light beam among the light beams emitted from the laser light sources in an outer region of the holographic ring, an objective lens to focus the light beams passed through the holographic ring lens on the respective information recording surfaces of the two types of the optical recording media, optical elements to alter optical paths of the light beams reflected from the information recording surfaces of the optical recording media, and two

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photodetectors to individually detect optical information from the light beams incident from the optical elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]   These and other objects and advantages of the invention will become apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a view showing the construction of a conventional optical pickup;

FIG. 2 is a view for explaining the structure of a conventional variable aperture shown in FIG. 1

FIG. 3 is a view showing an optical system of an optical pickup according to an embodiment of the present invention;

FIG. 4A is a view showing a positional relationship between a holographic ring lens and an objective lens according to the embodiment of the present invention, and

FIG. 4B is a view showing the plane surface of the holographic ring lens;

FIG. 5A is a view showing the plane surface of the holographic ring lens, and FIG.

5B is a graphical view showing that part of the FIG. 5A region which is enlarged;

FIG. 6 is a graphical view showing transmissive efficiency according to the groove depth of the holographic ring lens with regard to two wavelengths; and

FIG. 7 is a view showing that the holographic ring lens and the objective lens are integrally incorporated.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017]   Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below in order to explain the present invention by referring to the figures.

[0018]   FIG. 3 shows an optical system of an optical pickup according to an embodiment of the present invention. Referring to FIG. 3, the optical pickup apparatus includes two laser light sources 31 and 39 for emitting light beams having different wavelengths, respectively, two holographic beam splitters 32 and 40 for altering optical paths of the light beams reflected from information recording surfaces of first and second types of optical disks, a beam splitter 33 for

totally transmitting or reflecting the incident light beam according to the light wavelength, a collimating lens 34 for collimating the incident light beam to be in a parallel form, a holographic ring lens 35 for diffracting the incident light beam according to its wavelength, and an objective lens 36 for focusing the light beams on the respective information recording surfaces of optical disks 37 and 41. Two photodetectors 38 and 42 which detect the light beams reflected from the respective information recording surfaces of the optical disks 37 and 41 and the laser light sources 31 and 39 are integrally incorporated into single modules to form units 30 and 43, respectively. The operation of the optical pickup constructed above will be described below, in which a DVD and a CD-R are described as optical recording media.

[0019]   First, when recording and/or reading information on a DVD, a light beam having the 650 nm (or 635 nm) wavelength is emitted from the first laser light source 31 and is incident to the holographic beam splitter 32, in which the light is shown as a solid line. The incident light beam passes through the holographic beam splitter 32 and proceeds to the beam splitter 33. When recording and/or reading information about a CD-R, a light beam having the 780nm wavelength is emitted from the second laser light source 39 and is incident to the holographic beam splitter 40, in which the light is shown as a dotted line. The incident light beam passes through the holographic beam splitter 40 and proceeds to the beam splitter 33.

[0020]   The beam splitter 33 totally transmits the incident light beam of the 650 nm wavelength and totally reflects the incident light beam of the 780 nm wavelength. The totally transmitted or reflected light beam goes to the holographic ring lens 35 in the form of a parallel beam after passing through the collimating lens 34. The holographic ring lens 35 selectively diffracts the incident light beam according to the wavelength thereof, to prevent the generation of spherical aberration with regard to the light beams focused on the information recording surfaces of the optical disks 37 and 41.

[0021]   FIG. 4A is a view showing a positional relationship between the holographic ring lens 35 and an optical surface of the holographic ring lens 35. As shown in FIG. 4A, the objective lens 36 is partitioned into regions A and B. The region A, being closer to an optical axis of the objective lens 36, has little effect on a spherical aberration and the region B, being farther from the optical axis, has a large effect on the spherical aberration. Also, the objective lens 36 is most appropriate for a disk having a thin thickness such as a DVD. Thus, when a DVD is exchanged with a thick disk such as a CD-R to operate the optical pickup, the holographic ring lens 35 is required. If the holographic ring lens 35 is not used when recording and/or reading

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information on the CD-R, the spherical aberration in the beam spot formed on the information recording surface of the disk becomes large, in which the size is more than 1.7 μm. Generally, the size of the beam spot formed on the information recording surface of the CD-R is 1.41 μm. The holographic ring tens 35 diffracts the 780 nm wavelength light beam passed through the region F of the holographic ring lens 35 so as to prevent the generation of spherical aberration, for which a hologram depicted with dots in FIG. 4B is disposed on the region F of the holographic ring lens 35. Accordingly, the light beam which is incident to the region A of the holographic ring lens 35, passes through the objective lens 36 without any diffraction by the holographic ring lens 35, and then is directly focused on the disk. The region F of the light beam which is incident to the holographic ring lens 35, is wavelength-selectively diffracted by the holographic ring lens 35 and then proceeds to the objective lens 36. The diffracted light beam of 780 nm wavelength passing through the objective lens 36 makes the size of the beam spot focused on the disk smaller, and no spherical aberration is generated. A focal plane on which the diffracted 780 nm wavelength light beam passing through the region F is focused should coincide with an optimized surface of the disk on which the 780 nm wavelength light beam passing through the region A is focused. By using the holographic ring lens 35, a working distance from the surface of the objective lens 36 to the information recording surfaces of the disks becomes shorter in the CD-R 41 rather than in the DVD 37.

[0022]   FIG. 5A is a view showing the structure of the holographic ring lens 35. The holographic ring lens 35 has an inner region 351 including an optical center of the holographic ring lens 35, a holographic ring 353 centering at the optical center of the holographic ring lens 35 and surrounding the inner region 351, and an outer region 355 surrounding the holographic ring 353. In connection with FIG. 4A, the inner region 351 coincides with the region A, the holographic ring 353 coincides with the region F, and the outer region 355 coincides with the region B except the region F. A region D shown in FIG. 5B below where the hologram in the holographic ring lens 35 shown in FIG. 5A is provided on the holographic ring 353, corresponds to the numerical aperture of 0.3~0.5 which is intended to be appropriate to the CD-R. In FIG. 5A, a symbol E indicates the diameter of the objective lens for a DVD whose numerical aperture (NA) is 0.6. Also, the holographic ring lens 35 used in the present invention can selectively adjust the numerical aperture (NA) of the objective lens according to the wavelengths of the light beam, and requires no separate variable aperture. The holographic ring lens 35 has the same function as a general spherical lens which transmits a light beam in the convergent or divergent form. Further, the holographic ring lens 35 has a positive optical power and uses a phase shift

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hologram as a hologram formed in the holographic ring 353. An optimized depth of the grooves the hologram should be determined so that the holographic ring 353 selectively diffracts the incident light beam according to the wavelength thereof. The holographic ring lens 35 is constructed so that the light beam of the 650nm wavelength has transmissive efficiency close to 100%o and the light beam of the 780nm wavelength has a zero-order transmissive efficiency of 0% with respect to non-diffracted light beam. For that, in case that the holographic ring 52 has grooves of a constant depth the phase variation by the groove depth of the holographic ring should be about 360° with respect to the 650nm wavelength light. Since the phase variation is generated by 360°, the holographic ring lens 35 transmits most of the 650 nm wavelength light. The phase variation by the holographic ring 353 should be optimized with respect to the 780nm wavelength light, by which the 780nm wavelength light is all diffracted as first-order light. As a result, the holographic ring 353 is designed to hardly diffract the 650 wavelength light, but to diffract the 780 nm wavelength light as a first-order diffracted light. An optimized surface groove depth d of the holographic ring 353 for selectively diffracting 650 nm and 780 nm wavelength light beams is determined by the following equations (1) and (2).

$$\frac{2\pi d}{\lambda}(n-1) = 2m\pi$$

(1)

$$\frac{2\pi d}{\lambda'}(n'-1) = (2m'+1)\lambda$$

(2)

[0023] Here, λ is the 650nm wavelength, λ' is the 780 nm wavelength, and n and n' denote a reflective index (1.514520) in the 650 nm wavelength and a reflective index (1.511183) in the 780 nm wavelength, respectively. In the above equations (1) and (2), if m=3 and m' =2, the depth d becomes about 3.8μm.

[0024] FIG. 5B is a graphical view showing an enlarged view of the hologram region D shown in FIG. 5A. The hologram which is formed in the holographic ring 353 has grooves of a constant depth by etching or can be manufactured by molding. Further, grooves of the hologram can be formed stepwisely, together with a ring pattern. The grooves of the hologram can also be formed in a blazed type so as to maximize the diffraction efficiency on a non-zeroth order

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diffracted light.

[0025] FIG. 6 is a graphical view showing zero-order transmissive efficiency of the holographic ring according to the wavelengths of incident lights. When the surface groove depth d is 3.8μm, the 650am wavelength light is transmitted via the holographic ring 353 by 100% as shown in a solid line overlapped with the symbol "++", and the 780am wavelength light is transmitted via the holographic ring 353 by 0% as shown by a solid line overlapped with a circle. At this time, the holographic ring 353 diffracts the 780 nm wavelength light as the first-order light, in which diffraction efficiency thereof is 40%.

[0026] All of the 650 nm wavelength light incident to the holographic ring lens 35 having the above characteristics is transmitted and then proceeds to the objective lens 36. The incident light beam passes through the objective lens 36 and forms a beam spot on the information recording surface of the DVD 37. The light beam reflected from the information recording surface of the DVD 37 is incident to the holographic ring lens 35. After passing through the holographic ring lens 35, the reflected light beam is incident to the collimating lens 34, the beam splitter 33 and then to the holographic beam splitter 32, wherein the holographic beam splitter 32 directs the reflected light beam to the photodetector 38. The 780nm wavelength light incident to the holographic ring lens 35 is transmitted in the holographic lens 353 and then proceeds to the objective lens 36 as shown in FIG. 4A, but is diffracted in the region A and then proceeds to the objective lens 36. Therefore, the light beam passing through the objective lens 36 forms an optimized beam spot on the information recording surface of the CD-R 41. The light beam reflected from the information recording surface of the CD-R 41 is incident to the beam splitter 33 and then reflected. The reflected light proceeds to the holographic beam splitter 40 and then is incident to the photodetector 42 by altering the optical path.

[0027] The holographic ring lens 35 having the above functions may be manufactured integrally with an objective lens by being etched or molded to a constant depth inwards from one optical surface of the objective lens. The integrally incorporated holographic ring lens has the same function as the holographic ring lens 35. FIG. 7 is a view showing that the holographic ring lens and the objective lens are integrally incorporated.

[0028] As described above, the optical pickup apparatus according to the present invention is used compatibly with a DVD and a CD-R, by using a holographic ring lens to eliminate a spherical aberration generated in response to a disk being changed to another disk having a

different thickness, in which a working distance is shorter in the case of the CD-R than the DVD. Also, the optical pickup apparatus provides advantages which include ease in construction of a holographic ring lens and good mass-production capabilities.

[0029]   While only certain embodiments of the invention have been specifically described herein, it will be apparent that numerous modifications may be made thereto without departing from the spirit and scope of the invention.